Extreme Physics

a.k.a. Science Working Group 5
(compact objects; high density matter; physics of accretion)

Frits Paerels, Feryal Özel, Chris Reynolds, chairs
with 35 members signed up

XRS STDT F2F, DC, 11-(14,15)-2016

Five Great Science Topics

Fundamental Properties of Matter at Supranuclear Density:
- neutron stars at known distance (Globular Clusters)
- neutron stars in SNR ('CCO's')

Ultraluminous X-ray Sources and *bona-fide* SuperEddington Accretion

Microlensing in Multiply-lensed Quasars:
Accretion Flow Near the Event Horizon

Accretion onto BH, all scales

Other Great Science with XRS

Observatory Design Requirements

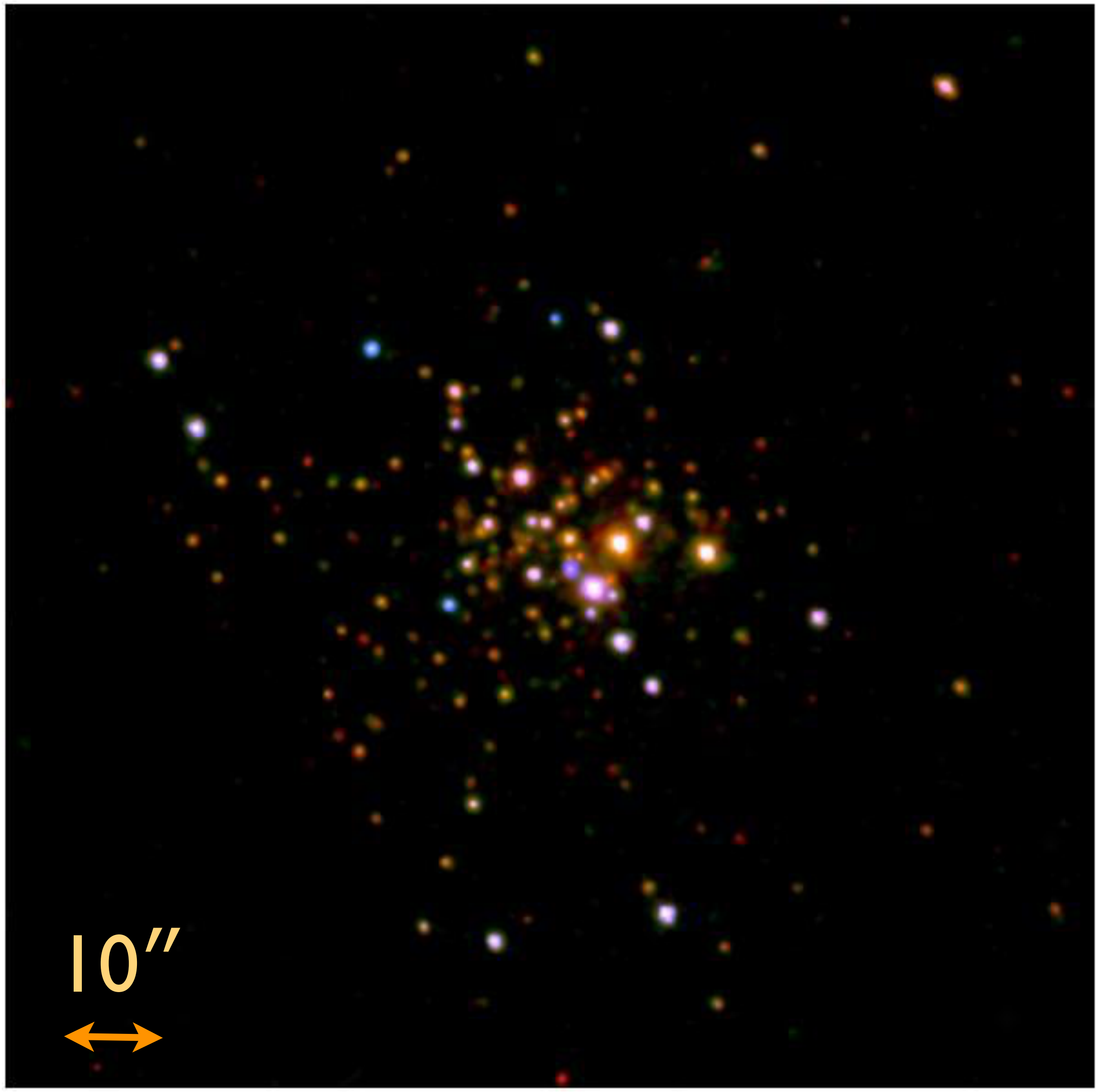
Bright Source Capability (probably unique to this SWG)

Five Great Science Topics

Angular resolution, effective area

Fundamental Properties of Matter at Supranuclear Density

1. Neutron Stars in Globular Clusters



47 Tuc/ *Chandra*; Heinke *et al.*, 2005

neutron star at known distance;
photospheric spectrum:
measure T_{eff}, log g: calculate R

differentiate between pure H, pure He composition: collect 10^6 counts in 10^5 sec(*); with wide bandpass, down to .2 keV: measure log g (broadband curvature)

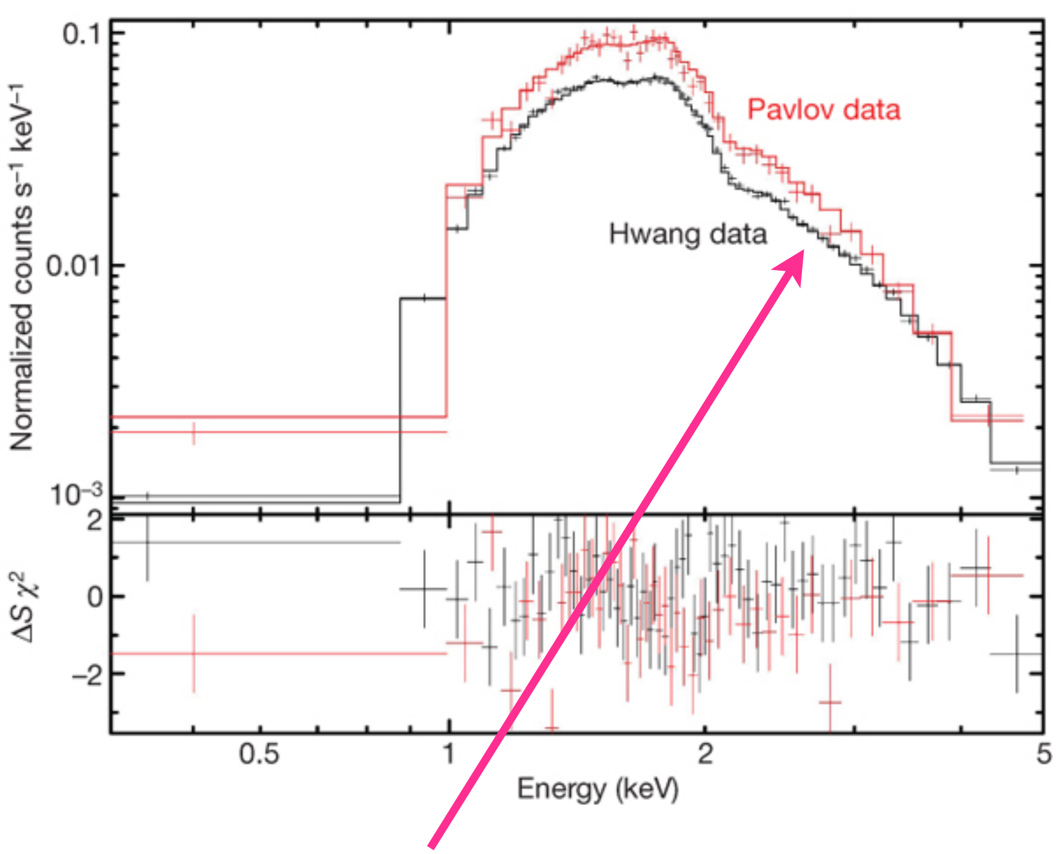
(*) standard configuration; µCal

Five Great Science Topics

Angular resolution, effective area

Fundamental Properties of Matter at Supranuclear Density

2. Neutron Stars in Supernova Remnants:
'Central Compact Objects'



Chandra, 1 Msec

same idea as previous;
neutron stars of known distance and age;
evidence for $Z \geq 6$ surface composition (from *a priori* constraint on radius)

CCO in Cas A/ *Chandra*; Ho & Heinke 2009

Ultraluminous X-ray Sources and *bona-fide* SuperEddington Accretion

Recent discovery of coherent pulsations in some ULX:
NS, so $M < 2M_\odot$ and $L > L^{iso}_{Edd}$

Understanding ULX population:
constrains (S/I)MBH population (formation, growth)

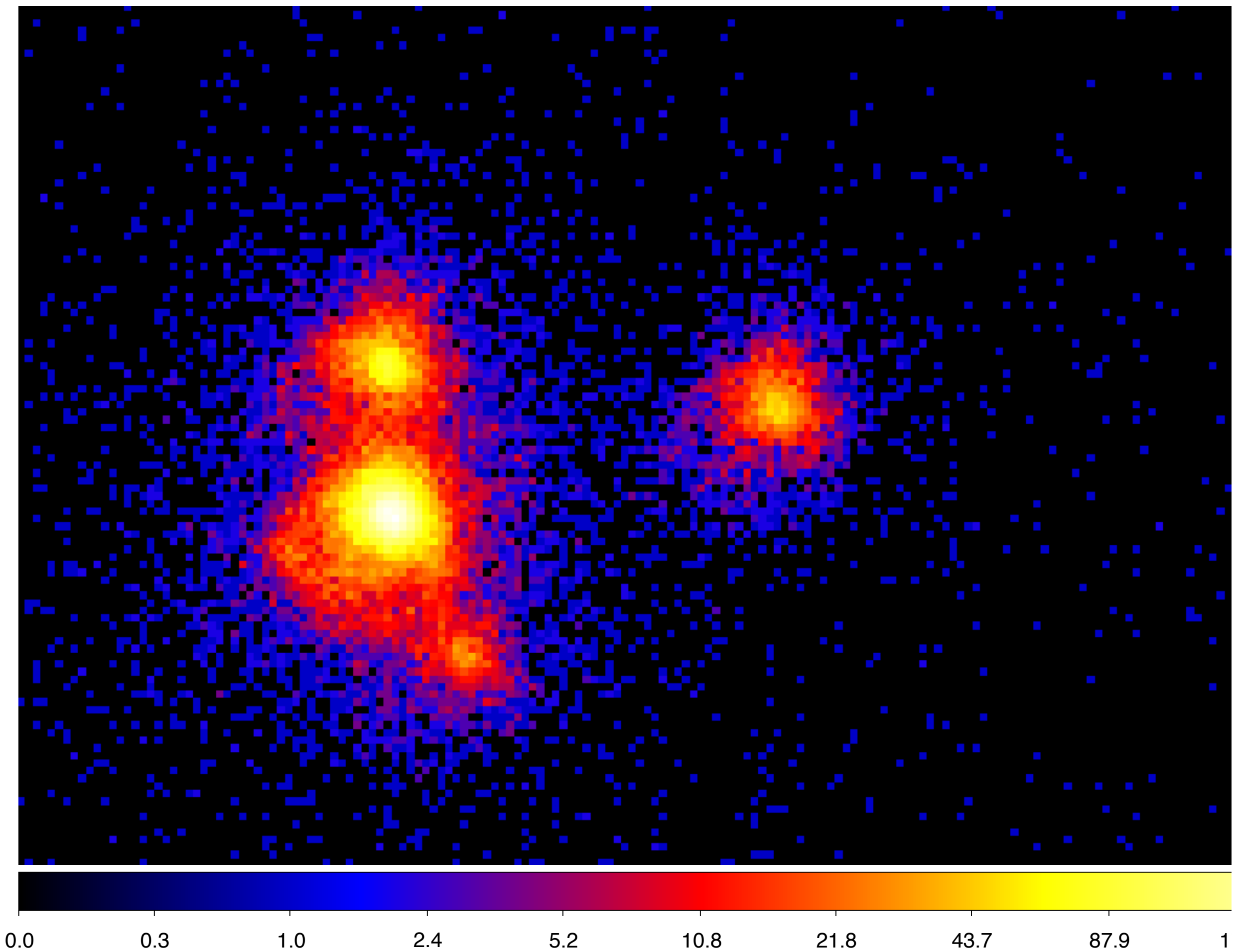
Three goals with XRS:

- study *bona-fide* superEddington flow (spectroscopy, variability)
- find more NS ULX's (detect pulsations; sources in crowded fields)
- study cosmic evolution of ULX population (byproduct of "first accretion light" surveys)

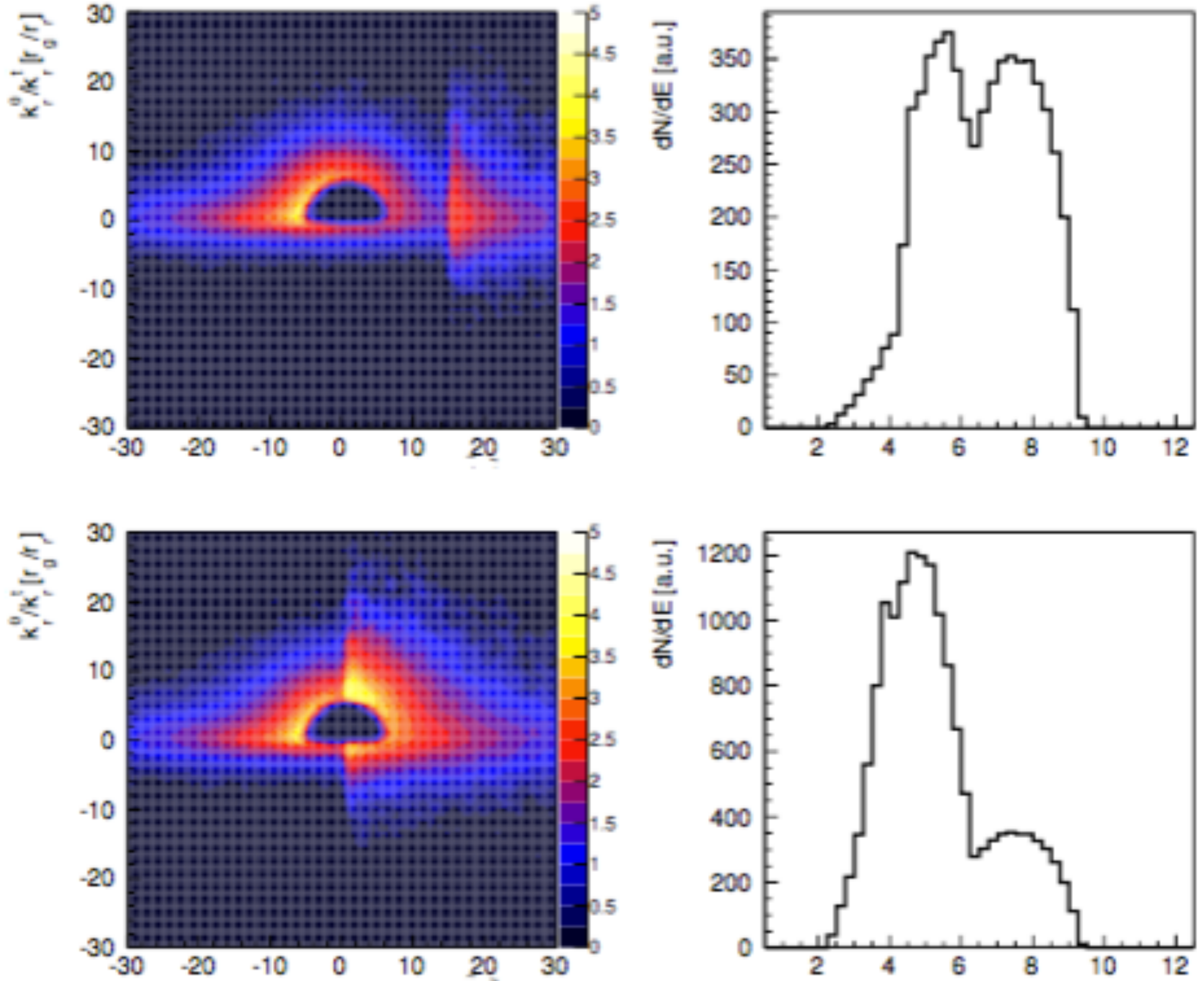
Angular resolution, effective area

Five Great Science Topics

Microlensing in Multiply-lensed Quasars: Accretion Flow Near the Event Horizon



RXJ 1131-1231/*Chandra* ACIS 28 ksec exp



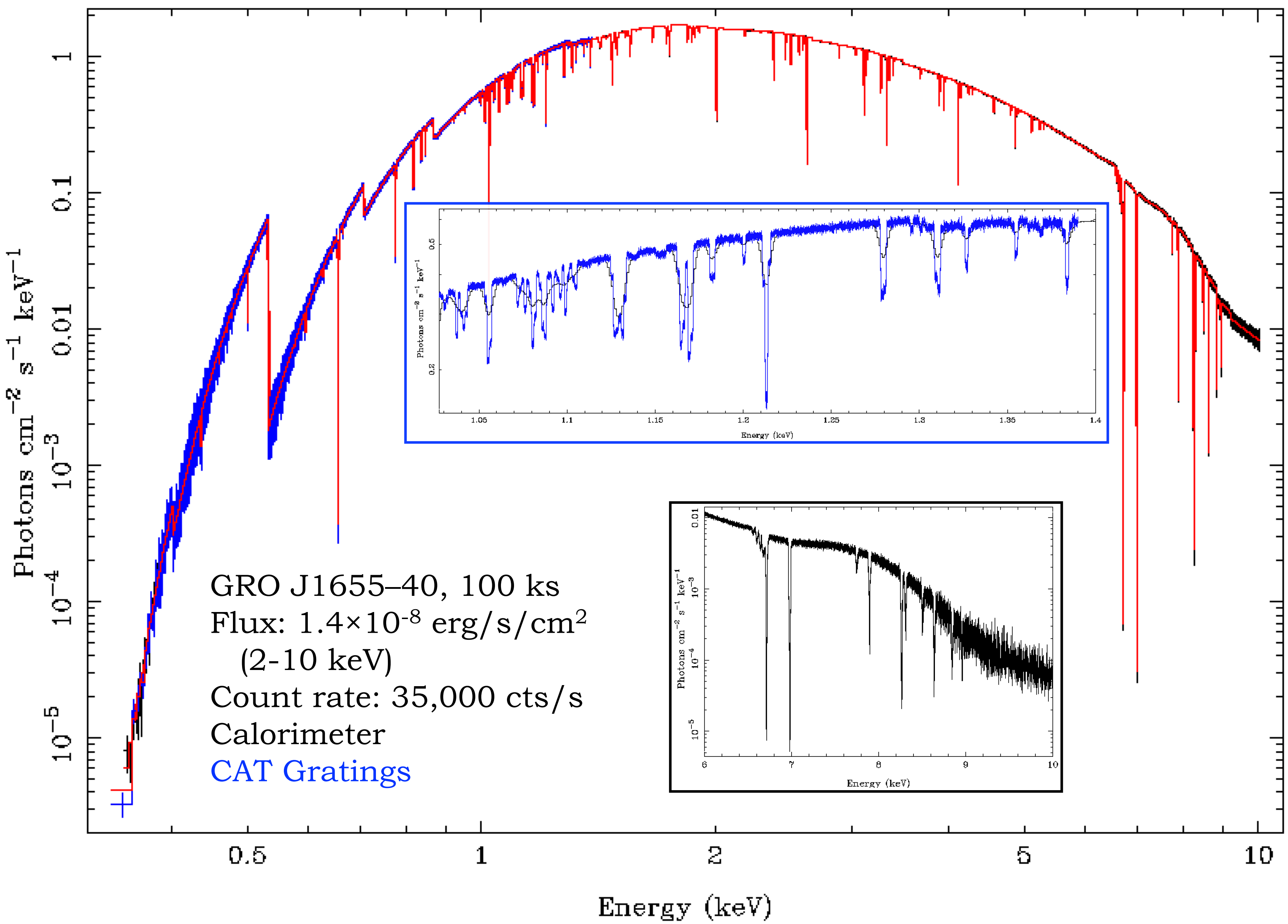
microlensing variability in Fe K from near event horizon (Krawczynski & Chartas 2016)

Angular resolution, effective area (at ~ 3 keV/ Fe K at z=1)

Five Great Science Topics

arguments for R > 5000 grating spectrometer

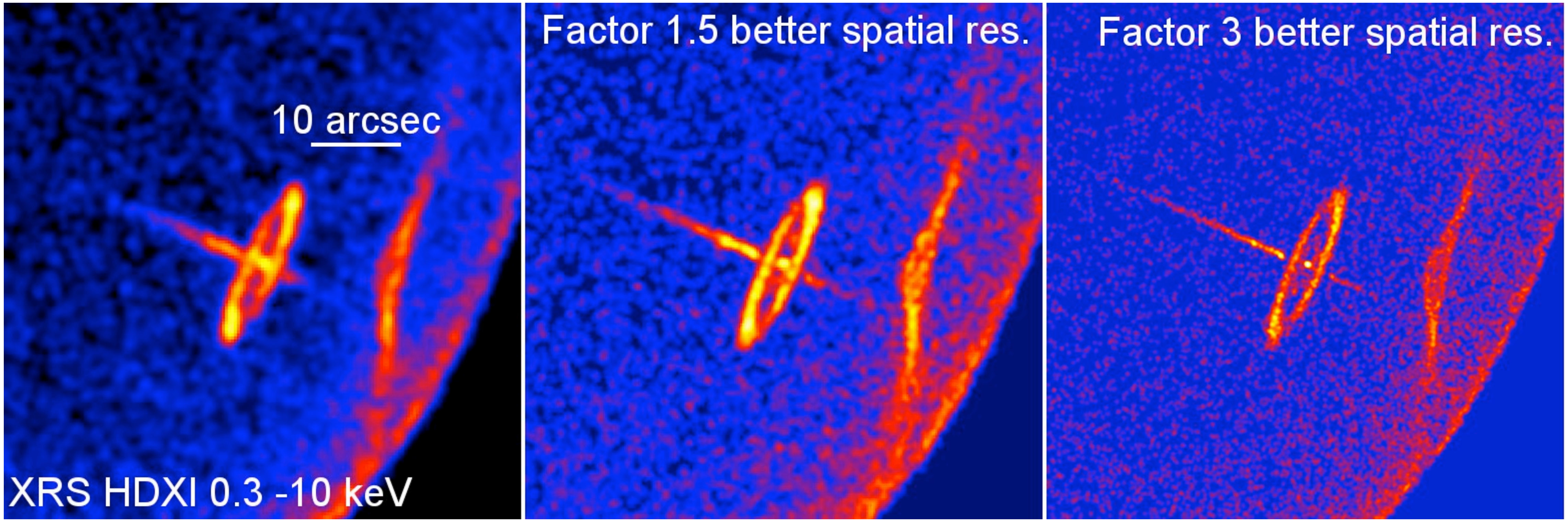
BH Accretion; ‘outflows’, winds, ...



Other Great Science with XRS

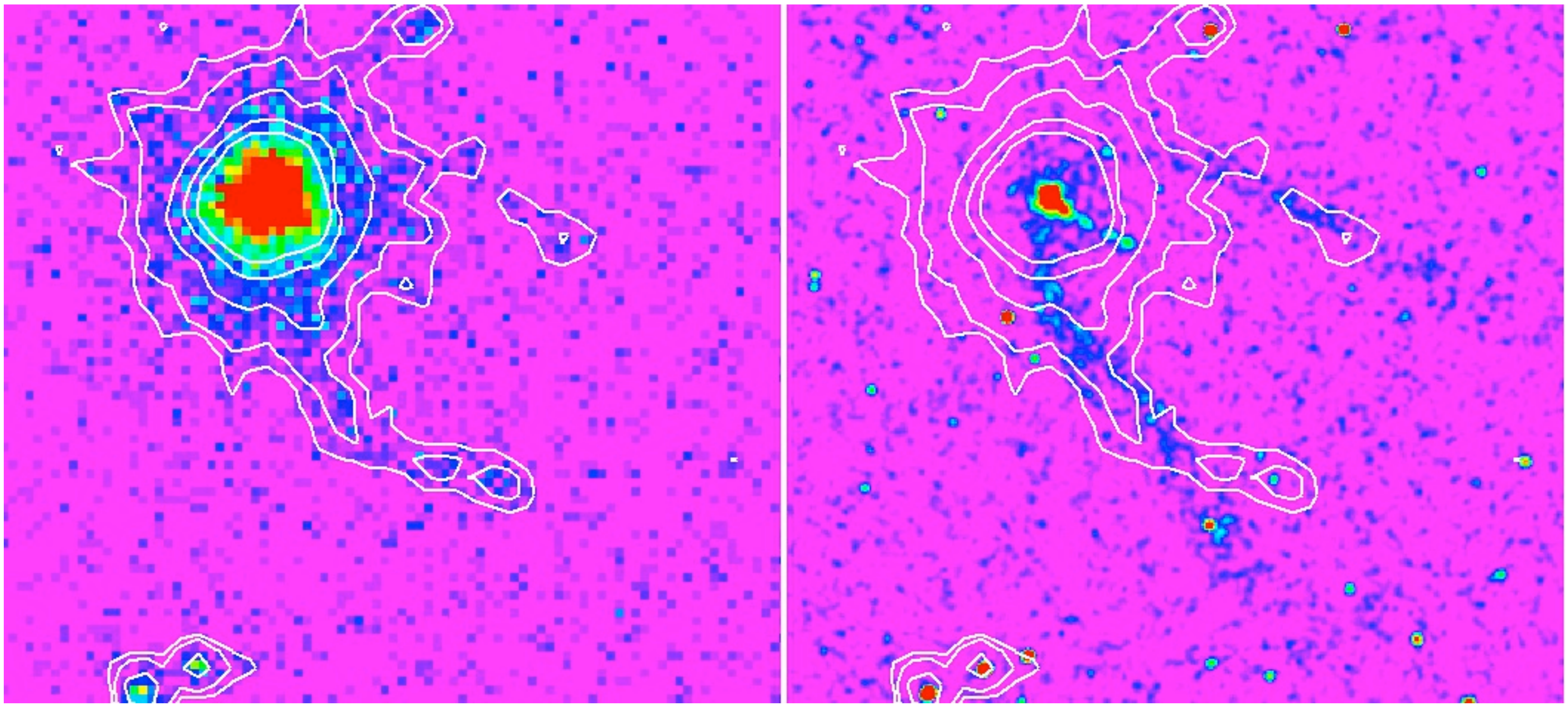
The power of high resolution imaging: demonstrated by HST, *Chandra*

XRS example: pulsar wind nebulae



Other Great Science with XRS

XMM image quality *Chandra* image quality

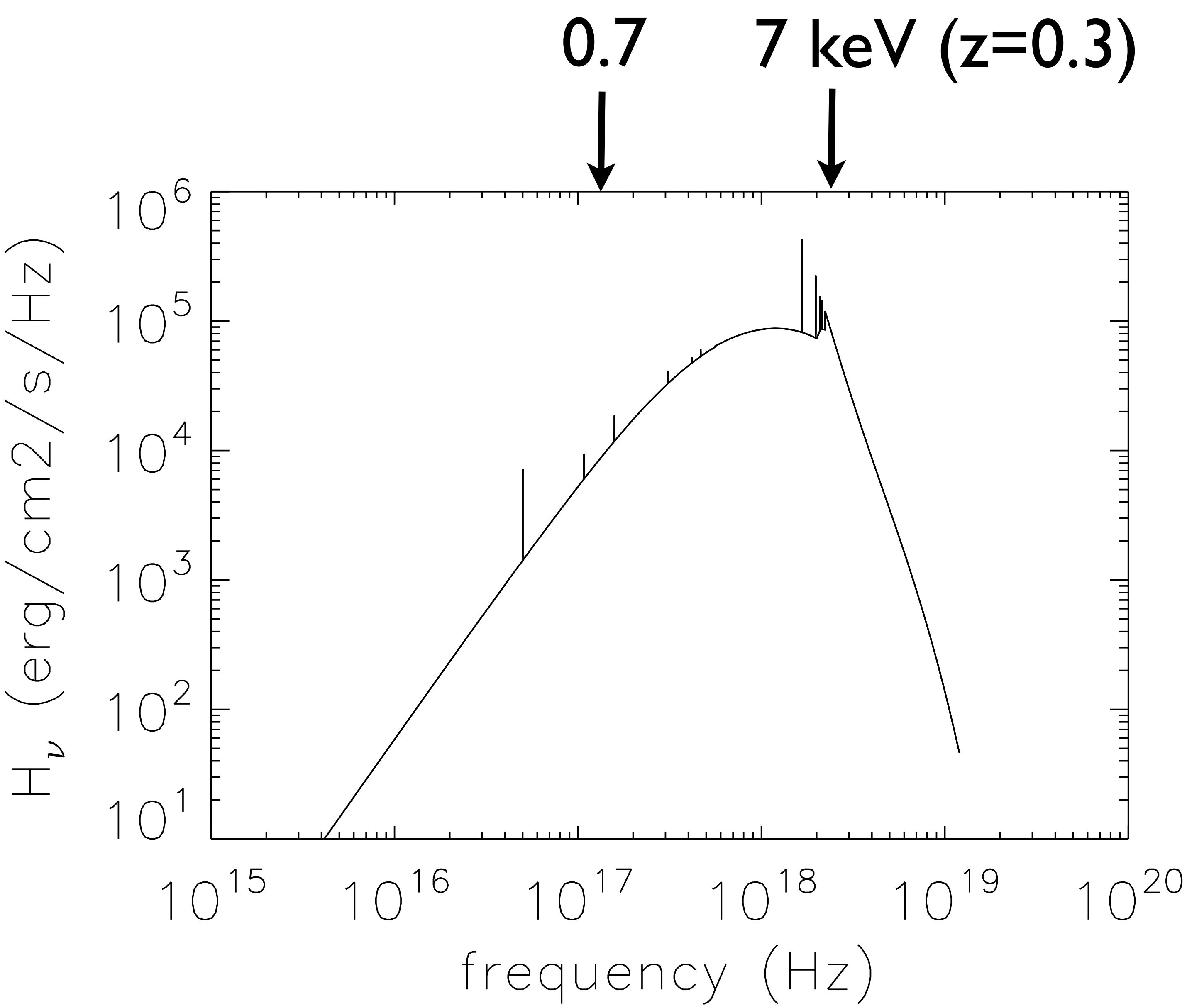


nearby pulsar: Geminga

once $\delta\varphi < 0.5$-1 arcsec: qualitative change

Other Great Science with XRS

thermonuclear X-ray bursts from NS: photospheric spectroscopy; M-R relation from multiply redundant diagnostics



if linewidths thermal, $\Delta E/E \sim 2\ 10^{-4}$

$T_{eff} = 1.5\ 10^7$ K
$\log g = 14.6$
Fe/H ~ Solar

Observatory Design Requirements

XRS 'standard' configuration ("20,000 cm^2 at 1 keV")

topic	exposure (10^3 sec)	ang. res. (arcsec)
NS in GC	100	< 0.5
NS in SNR	100	< 0.5
ULX	100/10^4/40	< 0.5
QSO µlensing	30?	< 0.5

ULX:

accretion flow spectroscopy/variability

trace population to high z: 10 counts from 10^{40} erg/s at z=5

detect pulsations: 1000 counts in 40 ksec (10^{40} erg/s out to z=0.1)

Observatory Design Requirements:
comments on bright source capabilities

three practical examples:

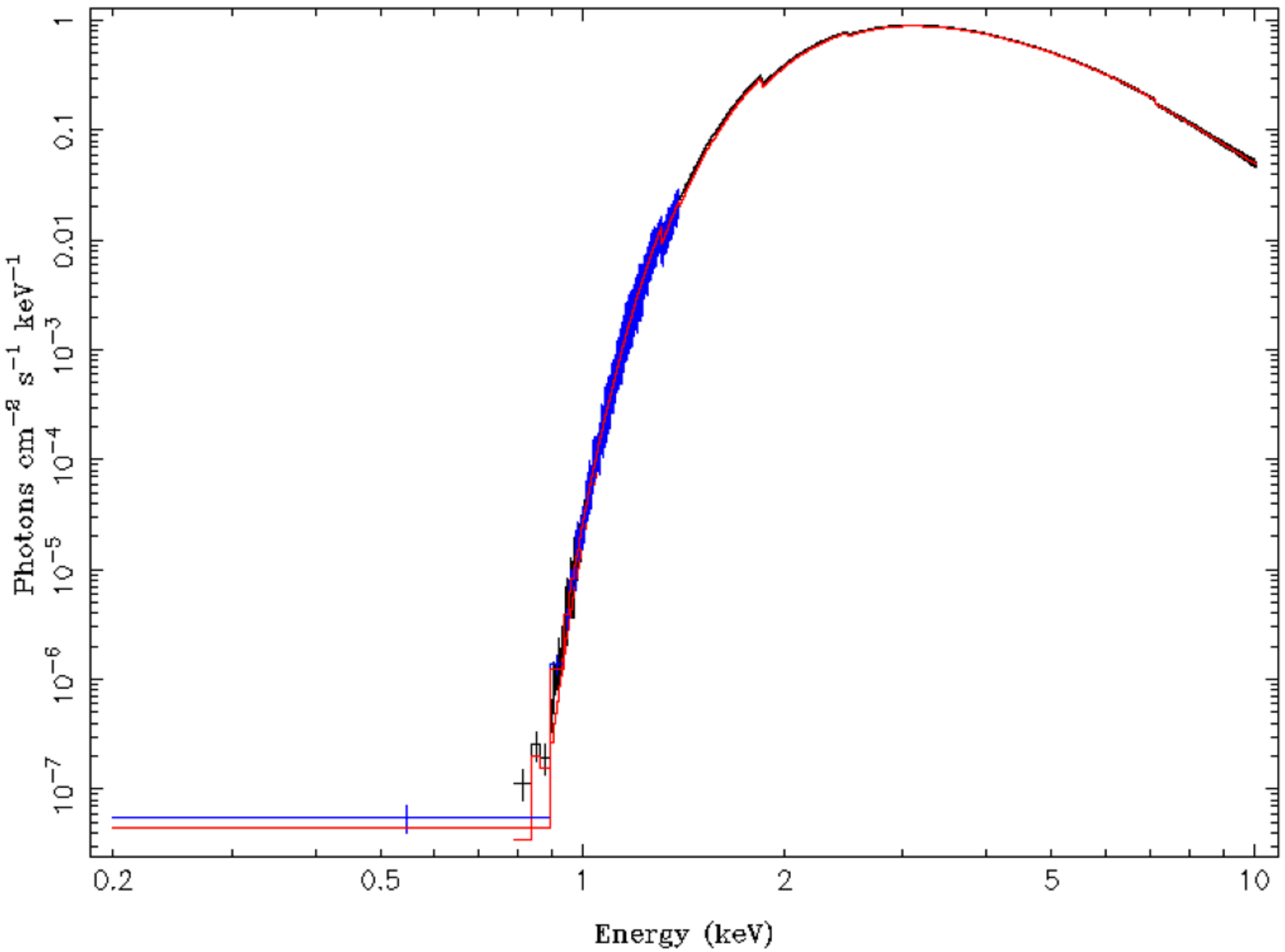
1. bright thermonuclear burst from SAX J1808.4-3658

microcalorimeter: 250,000 counts/sec for 10 seconds;
with CAT grating: 18,000 counts/sec for 10 seconds

Observatory Design Requirements: comments on bright source capabilities

2. bright steady point source: GRS1915+105

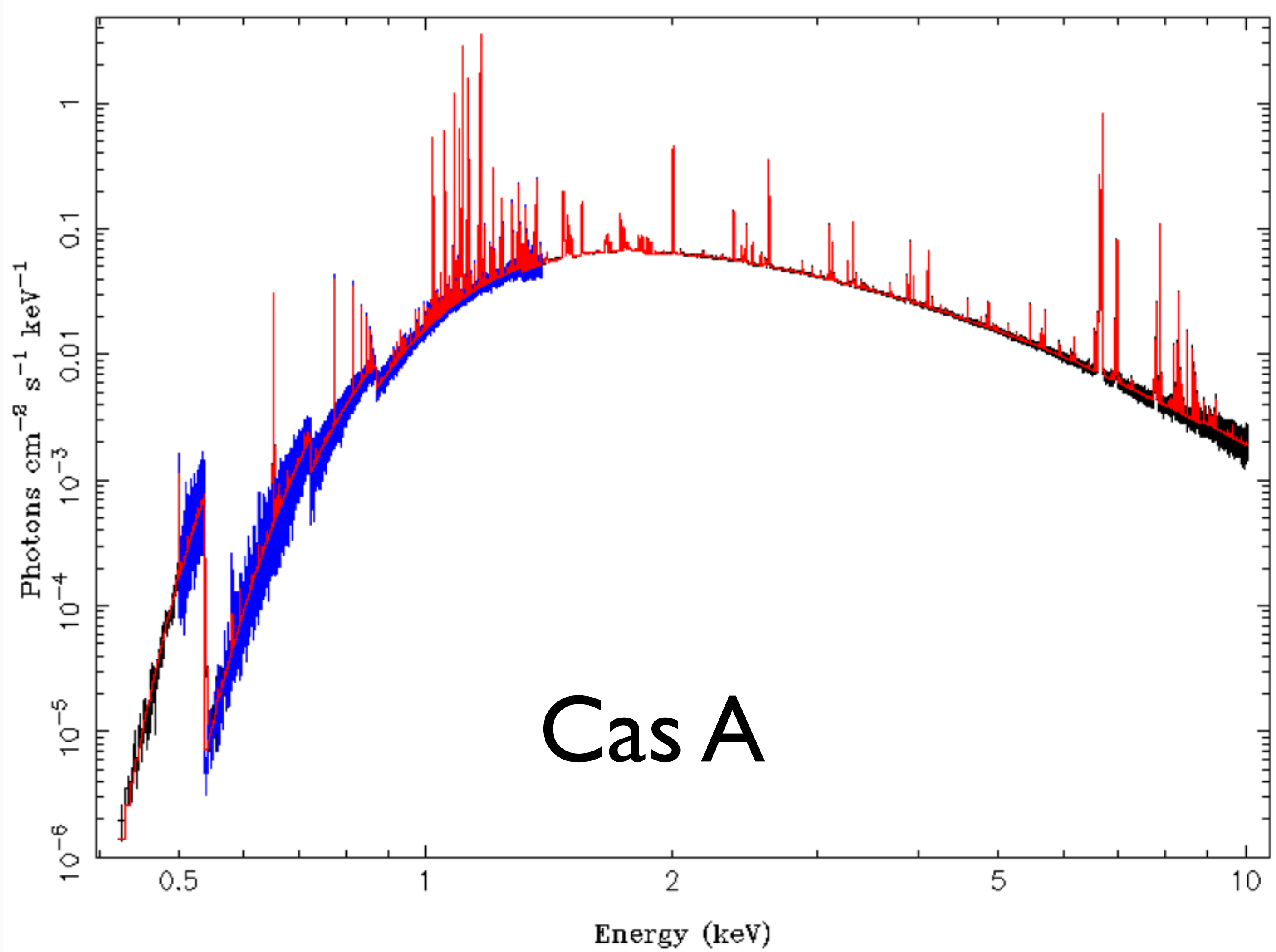
microcalorimeter: 10,000 counts/sec



Observatory Design Requirements:
comments on bright source capabilities

3. bright extended source: Cas A

1500 counts/sec, full microcalorimeter array



Observatory Design Requirements:
comments on bright source capabilities

4. and then there is the Crab...

90,000 counts/sec, full microcalorimeter array

Factors for consideration:
physical ('pileup') limits in microcalorimeter ($\tau_{thermal}$);
total processing/storage/transmission limits;
mitigation strategies for point sources (off-axis, defocus, ..);
use of the grating spectrometer